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Abstract

ENGINEERING AND PERFORMANCE OF UO_2 FUEL ASSEMBLIES

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1. The prototype 20-MW(e) NPD and the full-scale 200-MW(e) CANDU are the first of a series of Canadian power reactors based on heavy-water moderation, heavy-water cooling and natural-uranium fuel. The key to low-cost power from reactors of the CANDU type lies with low fuelling costs. The purpose of this paper is to show how CANDU-type fuel has been engineered for burn-ups in excess of 10 000 MWd/tonne U to yield total fuelling costs of less than 0.8 mills/kWh. The following points are discussed:

NEUTRON ECONOMY IN DESIGN

2. The fuel is made up of elements 15.2 mm in diameter which are assembled in clusters of 19 to make "bundles" 49.5 cm long. Several bundles stacked end to end make up the fuel charge in one channel (82.5 mm I.D.). This design allows bidirectional fuelling and hence radial flux flattening and uniform burn-up of all the fuel in each channel.
3. The UO_2 is clad in Zircaloy-2 and a fuel/cladding weight ratio of 10 is achieved principally by designing for cladding (0.38 mm thick) that will collapse on to the fuel under the pressure of the coolant.
4. A detailed discussion is given of the problems associated with meeting the hydraulic, thermal, structural and dimensional limitations imposed by the requirements for compatibility with the Zircaloy pressure-tube assembly and with the on-power fuelling machine.

IRRADIATION PERFORMANCE

5. The CANDU and NPD programs have placed heavy emphasis on irradiation testing. Fifty-four experimental, full-scale prototype fuel assemblies have been irradiated at coolant temperature and pressure

covering a range of heat ratings ($\int \lambda d\theta$) from 20 to 55 W/cm (maximum nominal rating for CANDU is an $\int \lambda d\theta$ of 40 W/cm).

6. Fuel loading of NPD was completed in March 1962; since then the first charge has logged 210 equivalent-full-power days of operation, mostly at full rating. As yet none of the 1188 fuel bundles has failed. Sample bundles extracted from the highest-rated positions have been found to be in excellent condition.

FUEL COST

7. CANDU first charge has been purchased at a fixed price which assures fuelling costs of 1.1 mills/kWh $\pm$ 10%. Based on NPD and CANDU fuel manufacturing experience, estimates indicate that the expansion of throughput to meet a 1000-MW(e) capacity will bring fuelling costs down below 0.8 mill/kWh. This economy has been achieved by engineering the fuel design and fabrication methods to be mutually compatible. The development of resistance welding has been a major factor in reducing fabrication costs.
8. Emphasis has been placed on the evolution of product specifications.

FUTURE POTENTIAL

9. Experiments are underway to increase allowable heat rating and introduce boiling to improve channel output. Concurrently, innovations are being introduced to further reduce the Zircaloy inventory and simplify fabrication methods.
10. Preliminary experiments on full-scale prototype fuel bundles have been successfully completed with heat ratings 130% of those for CANDU, with boiling in the channel to give as much as 13wt% steam at the outlet, and to a calculated burn-up of 7000 MWd/tonne U.